
Antiproton Acceptance

Steve Werkema
Temple Review
July 1, 2003

Scope

Two Projects:

1. High Gradient Lithium Lens Upgrades

Project Leader: Jim Morgan

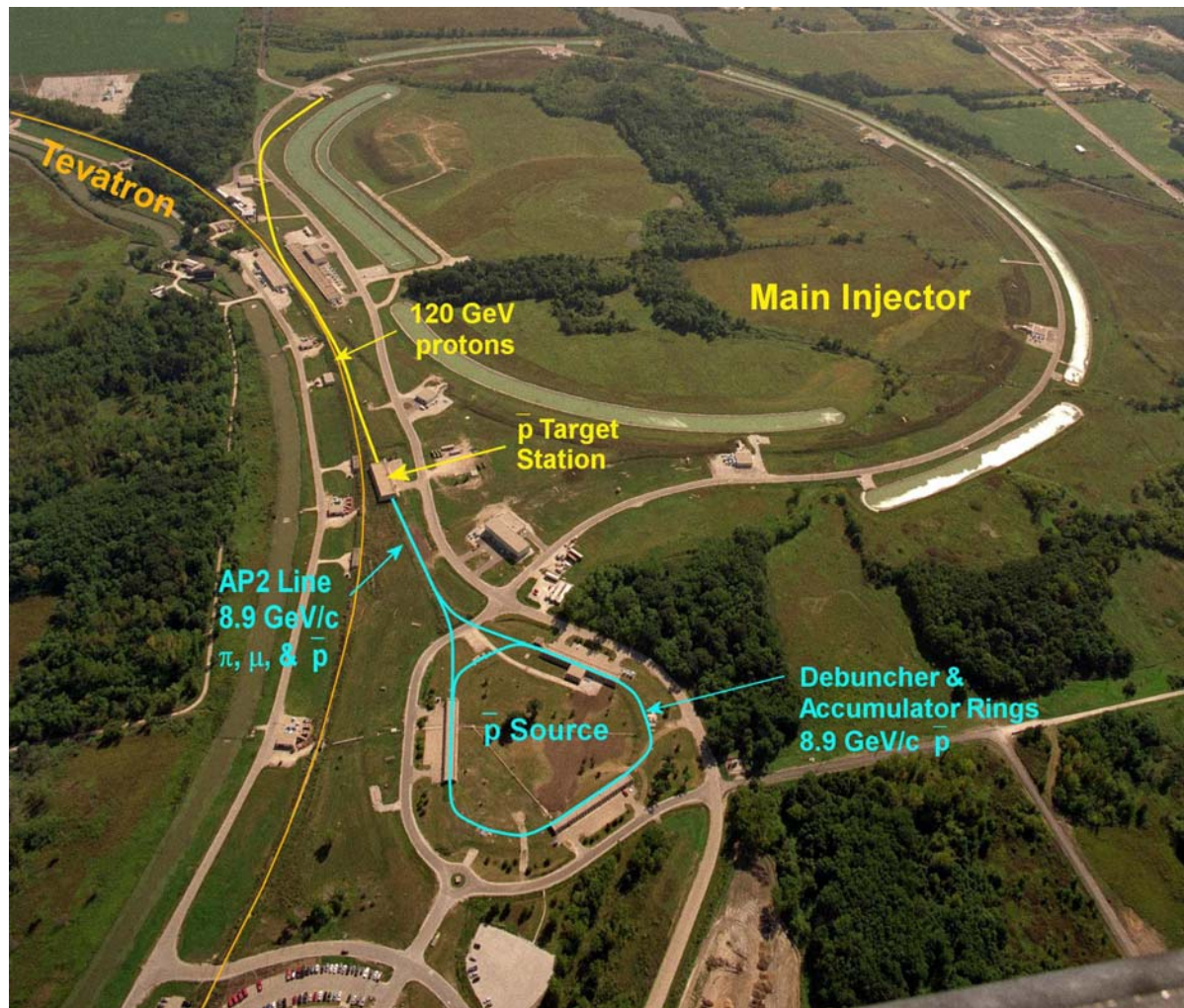
2. AP2 Beamline and Debuncher Acceptance Improvements

Project Leader: Keith Gollwitzer

Layout

Layout of Antiproton Acceptance projects:

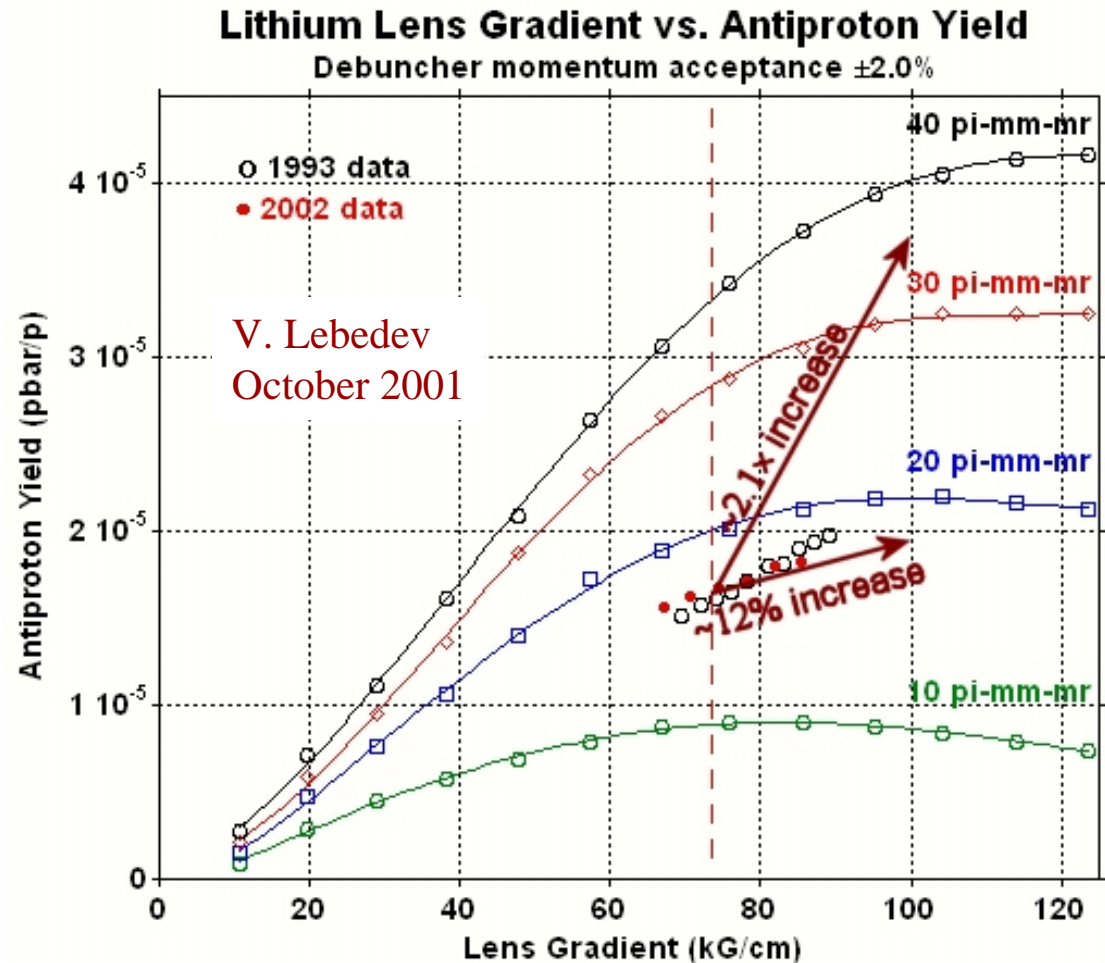
- Target station - downstream of target
- AP2 beamline
- Debuncher ring



Motivation

Increase the number of antiprotons collected from the target by:

- increasing the gradient of the collection lens
- increasing the admittance of the AP2 beamline and the Debuncher



WBS Overview

WBS	Subproject	In Charge	Finish Date	M&S Est	M&S Cont
1.3.2	Pbar Acceptance	Steve Werkema	1/10/07	\$2,036,000.00	62%
1.3.2.1	Lithium Lens Upgrades	Jim Morgam	1/10/07	\$673,000.00	48%
1.3.2.1.1	Modifications to existing lens	Pat Hurh	1/7/05	\$22,000.00	40%
1.3.2.1.2	New lens design	Pat Hurh	1/12/05	\$126,000.00	45%
1.3.2.1.3	General lens R&D	Pat Hurh	10/3/03	\$75,000.00	59%
1.3.2.1.4	New Lens Operational (Milestone)	Pat Hurh	1/12/05	\$0.00	
1.3.2.1.5	Fabricate new lenses	Pat Hurh	1/10/07	\$450,000.00	47%
1.3.2.2	AP2 and Debuncher Acceptance	Keith Gollwitzer	12/4/06	\$1,363,000.00	69%
1.3.2.2.1	Assemble documentation & drawings	Dave VanderMeulen	9/9/03	\$0.00	
1.3.2.2.2	Optical Survey & Alignment	Keith Gollwitzer	10/3/03	\$0.00	
1.3.2.2.3	Instrumentation	Keith Gollwitzer	9/26/06	\$194,000.00	86%
1.3.2.2.4	Beam based alignment (BBA)	Keith Gollwitzer	9/27/05	\$0.00	
1.3.2.2.5	Redesign/modify/rebuild/relocate elements	Keith Gollwitzer	12/4/06	\$967,000.00	76%
1.3.2.2.6	Orbit Control	Keith Gollwitzer	8/10/05	\$202,000.00	20%
1.3.2.2.7	Increase admittance of the Debuncher injection channel	Ina Reichel (LBL)	10/11/04	\$0.00	
1.3.2.2.8	Develop model of AP2 and Debuncher lattice	Keith Gollwitzer	1/21/05	\$0.00	
1.3.2.2.9	AP2 and Debuncher Acceptance Beam Studies	Keith Gollwitzer	7/18/05	\$0.00	

Major cost drivers:

Li Lens Upgrades

- \$450K - Fabrication of 4 new lenses (all will be operational lenses)

AP2 & Debuncher Acceptance

- D4Q4 Magnet replacement (\$115K) and injection septum rebuild (\$200K) under WBS 1.3.2.2.5
- \$500K - Mitigate yet to be determined aperture restrictions
- \$100K - "New" instrumentation under WBS 1.3.2.2.3
- \$200K - Debuncher motorized quad stands under WBS 1.3.2.2.6

High Gradient Li Lens - Goals & Plan

- Goal: Operate a Lithium lens --

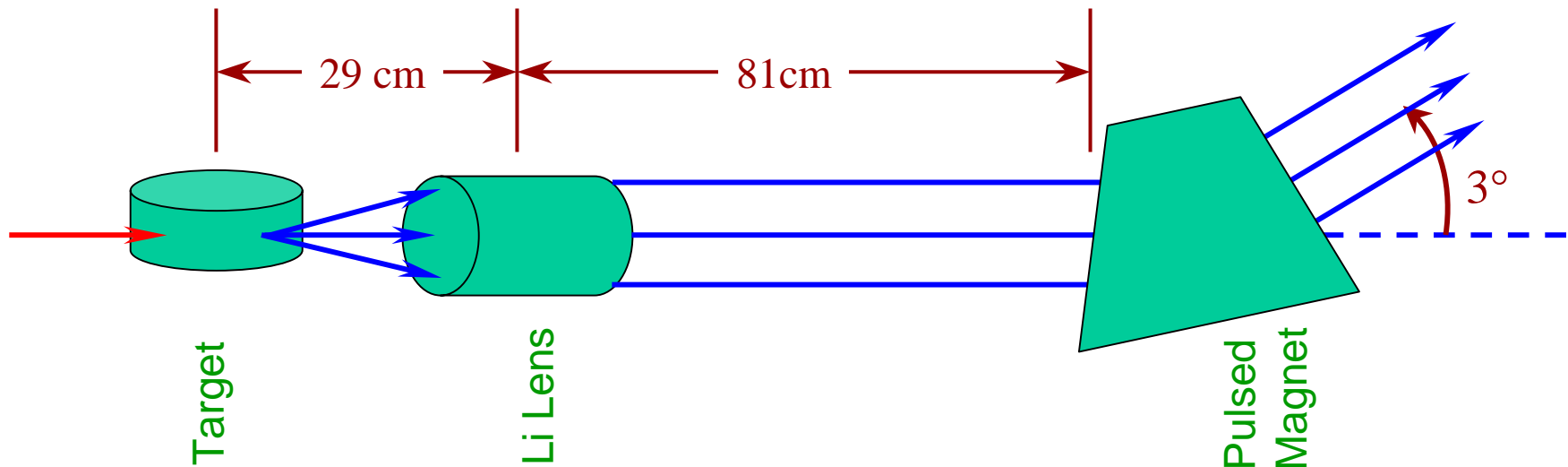
- at a gradient of at least 1000 T/m (34% ↑)
- for at least 10 million pulses

- Action Plan

- Improve present Li Lens design
- New solid Li Lens design (began 2000)
- General Li Lens R&D
 - Autopsies of failed lenses
 - FEA model of present design
 - R&D of various Lens technologies
- Fabricate New Lenses

High Gradient Li Lens -- Parameters

	Present	Upgrade
Gradient	745 T/m	1000 T/m
Radius	1.0 cm	1.0 cm
Length	15 cm	15 cm
Lifetime	$\sim 9 \times 10^6$ pulses	10×10^6 pulses



High Gradient Li Lens -- Status

- Modifications to existing lens design

When present lens (Lens 24) fails, install a lens constructed with improved quality control procedures (Lens 28)

- Lens 24 was installed in May 2003. Should last for ~1 year.
- Operate 28 for 1 month at 745 T/m then increase to 820 T/m

- New Lens design

Complete and test new lens design prototype #1

- Fill - Late July 2003
- Begin testing on test stand by end of Summer 2003

- General Lens R&D

➤ Lens #22 autopsy to start soon

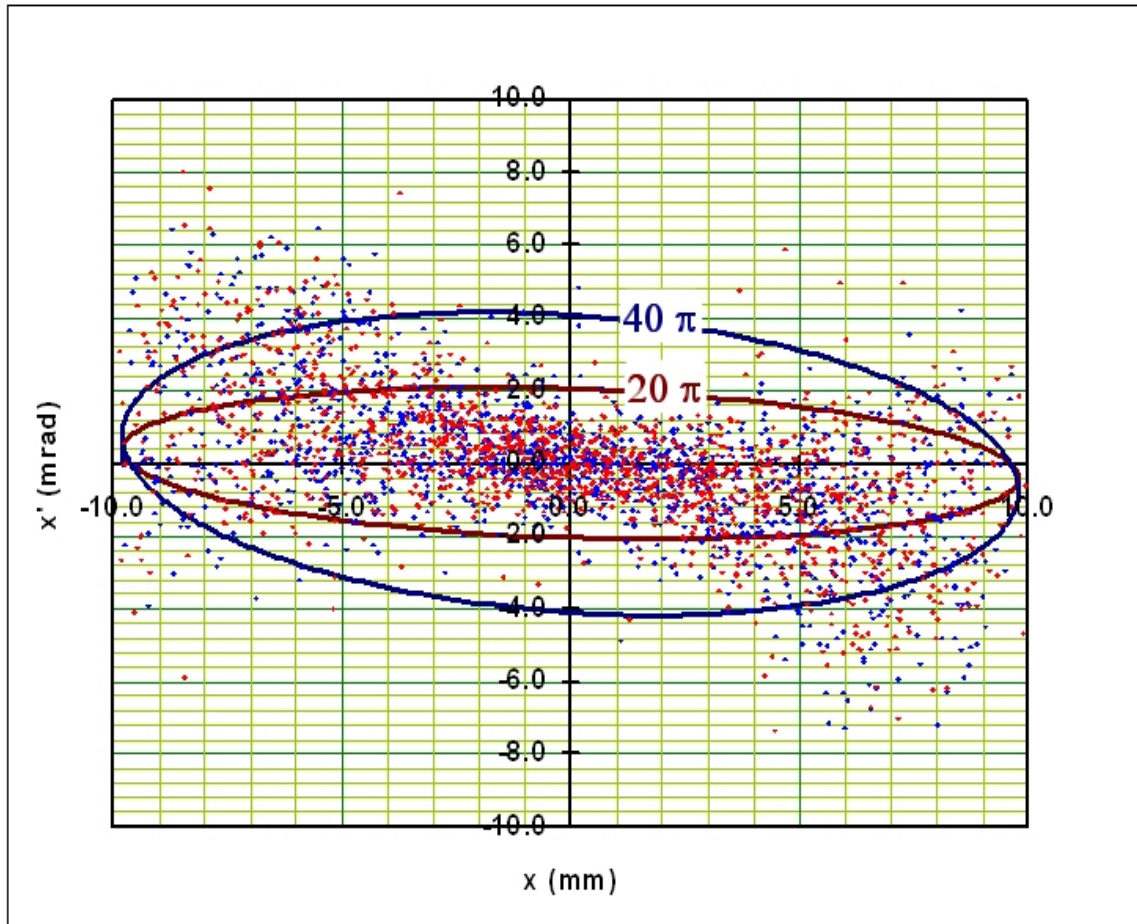
- 2nd longest lived lens (9.2 million pulses)
- Did not fail during pulsing

➤ Refine and expand FEA model

- Fabrication of new lenses

Construction of upgraded lenses scheduled to start in early 2005

AP2 & Debuncher Acceptance -- Motivation



\bar{p} phase space distribution exiting the lens for a lens gradient of 750 T/m.

$$\Delta p/p < 2.25\%$$

Blue dots are horizontal,
Red dots are vertical
(i.e. 2 points per \bar{p})

***Note:** the 20π and 40π ellipses represent two different AP2 lattices. The AP2 optics has been adjusted to match Li lens aperture.*

$$\beta_{lens} = \pi \frac{r_{lens}^2}{A_{AP2}}$$

Goal: 35π mm-mrad transverse admittance

AP2 & Debuncher Acceptance -- Parameters

	Recent Measurements	Physical Aperture	Goal
Horizontal (mm-mrad)	$20 \pm 1.5 \pi$	$40 \pi^{\dagger}$	35π
Vertical (mm-mrad)	$12 \pm 1.5 \pi$	$40 \pi^{\dagger}$	35π
Momentum	$\pm 2.25\%$	$\pm 2.25\%$	$\pm 2.25\%$

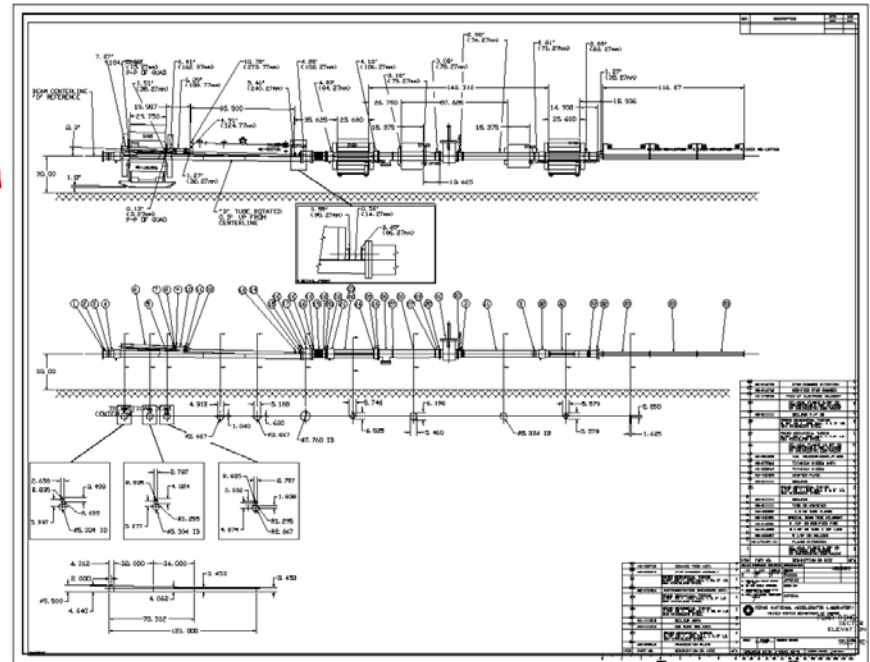
\dagger There are several locations where the physical aperture is known to be less than the admittance indicated in this table (e.g. Band 4 cooling pickups and kickers, Debuncher quadrupole D4Q4, DRF2 and DRF3 cavities).

AP2 & Debuncher Acceptance -- Plan

- Assemble Documentation and Drawings (FNAL Tech. Div.)
- Optical Survey and Alignment
- Instrumentation upgrades
 - AP2 BPMs
 - Debuncher BPM DAQ upgrade
- Beam Based Alignment
 - Develop procedures
 - Software development
- Mitigate aperture restrictions
 - Redesign/modify/rebuild/relocate beamline elements
- Orbit control
 - Install additional dipole trims in AP2
 - Motorized quad stands in the Debuncher
- Increase admittance of Debuncher Injection channel (LBNL)
- Develop AP2 and Debuncher Lattice models
- AP2 and Debuncher Acceptance beam studies

AP2 & Debuncher Acceptance -- Status (1)

- Documentation and Drawings
 - Debuncher injection region drawing complete
 - AP2 Physical Aperture table complete
 - Debuncher Physical Aperture table in process (complete by Fall 2003)
- Optical Survey
 - Scheduled for Fall 2003 shutdown



Debuncher injection region drawing

AP2 & Debuncher Acceptance -- Status (2)

● Instrumentation

● AP2 BPMs

- Presently unusable for reverse protons due to kicker ground surge
- Relocation of BPM electronics - Est. Completion: Fall 2003
- DAQ hardware & software upgrade - Est. completion: Fall 2004

● Debuncher BPM upgrade

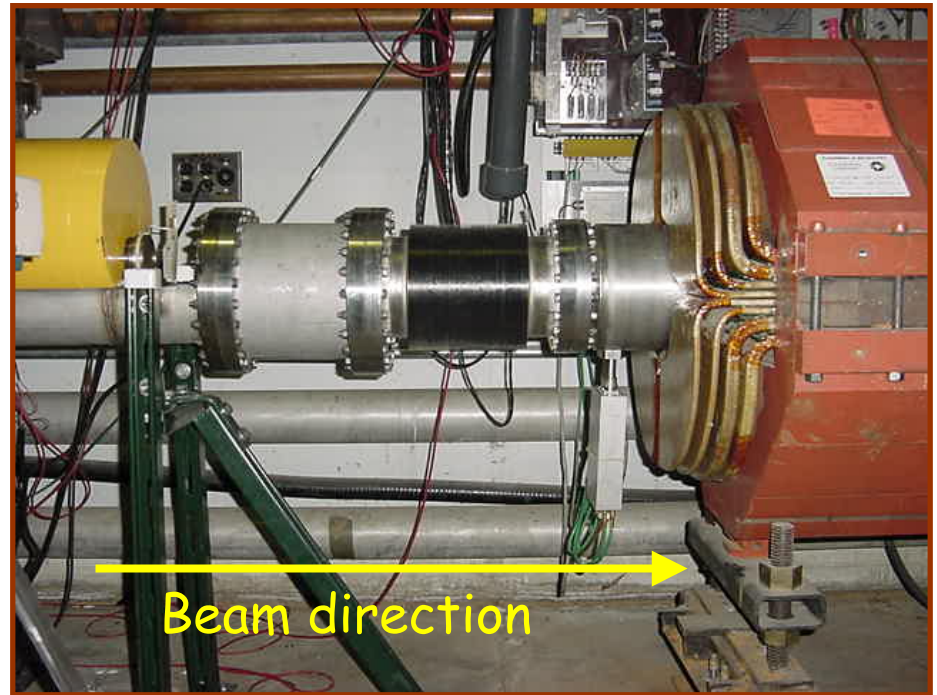
- One sector (1/6) of new electronics is in place and is being tested
- Remaining 5 sectors to be installed during Summer 2003 shutdown
- Completion of software development expected by Fall 2003
- Beam commissioning complete by mid 2004

● Beam Based Alignment

- Recent work: maintenance/upgrade of orbit correction console software

AP2 & Debuncher Acceptance -- Status (3)

- Redesign/modify/rebuild/relocate beamline elements
 - Most significant tasks:
 - Replace Debuncher quad D4Q4 with a large aperture quadrupole(s) Shutdown 2004
 - Replace Band 4 stochastic cooling tanks Shutdown 2004
 - Move Debuncher RF cavities DRF2 and DRF3 Shutdown 2004
 - Other tasks already identified (on WBS)
 - Tasks not yet identified



Debuncher injection. D4Q4 is on the right. Injected in upper portion of aperture, circulating beam is in the lower portion.

AP2 & Debuncher Acceptance -- Status (4)

- Orbit Control
 - AP2 line trim dipoles
 - 4 NDB dipole trims have been installed in the AP2 line during the past year
 - Install moveable stands on selected Debuncher quads
 - Cables were pulled during the January 2003 shutdown.
 - Install 10 stands in Fall 2003 shutdown
 - Install an additional 20 stands during the Summer 2004 shutdown
 - Expected Completion: Fall 2004
- Increase admittance of Debuncher injection channel (LBNL - Ina Reichel, Mike Zisman, John Corlett, and Massimo Placidi)
 - Review of Debuncher injection design - propose upgrades
 - Develop beam based alignment procedures
 - Status: Work started in April 2003. Presently collecting documentation and developing optics model and examining the effects of misalignments, strength errors, and matching errors on the AP2 acceptance

AP2 & Debuncher Acceptance -- Status (5)

- AP2 and Debuncher Lattice modeling
 - Working OptiM models of the AP2 line and the Debuncher exist
 - The models are being updated with alignment and physical aperture information as the data becomes available
- Beam Studies

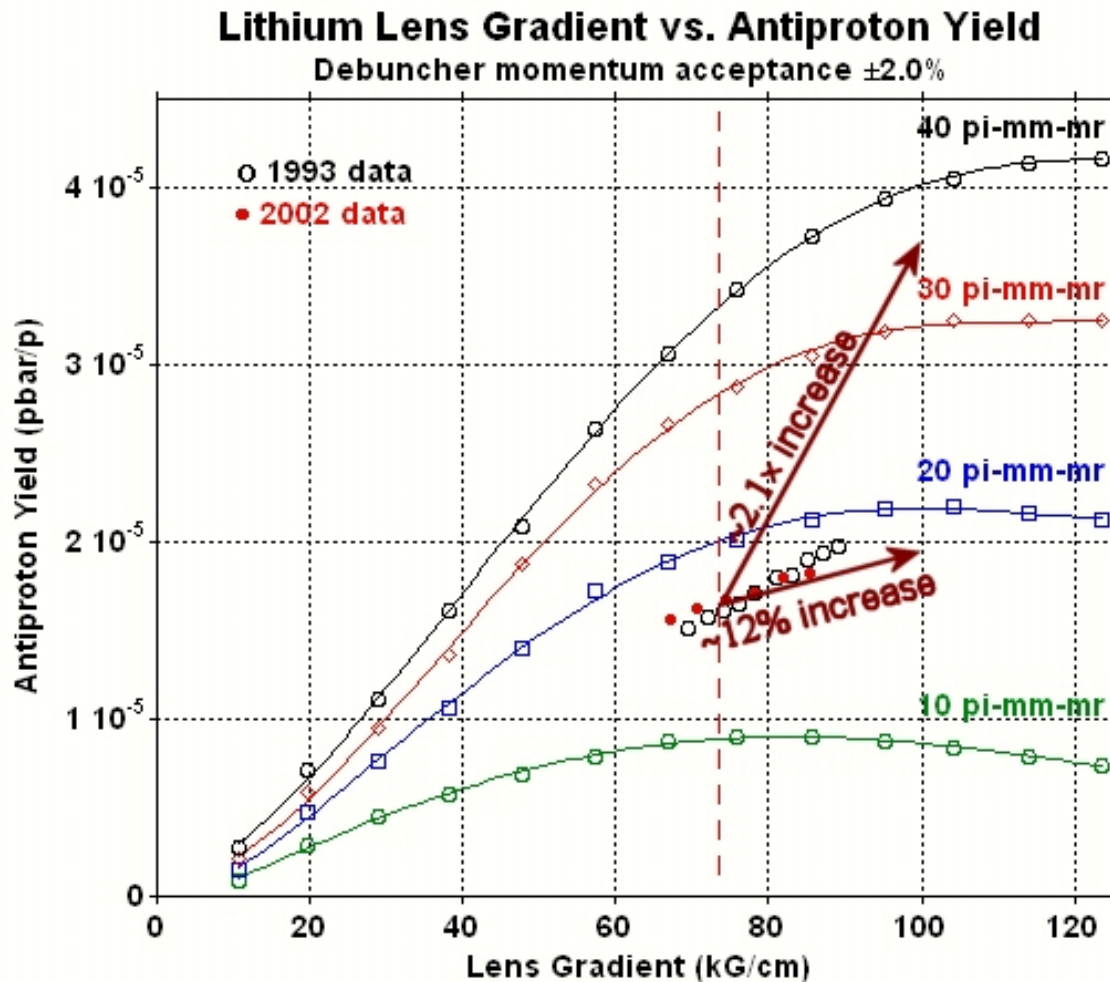
Completed studies:

 - ❖ Reverse proton studies
 - Re-commission and develop various beam manipulation procedures (Debuncher, AP2, DRF3, DRF1) (40 hr)
Problem: have not yet been able to see beam on AP2 BPMs
 - Debuncher BPMs (Re-commission old electronics and prototype testing of new electronics) (8 hr)
 - Aperture measurements (4 hr)
 - ❖ Stacking studies
 - AP2 line orbit correction (12 hr)
 - Measure AP2 + Debuncher admittance (develop measurement techniques) (20 hr)
 - Measure AP2 + Debuncher momentum aperture (8 hr)

Milestones

WBS	Subproject/Milestone	MS Class	MS Date
1.3.2	Pbar Acceptance		
1.3.2.1	Lithium Lens Upgrades		
1.3.2.1.2	New lens design		
1.3.2.1.2.1.5	Prototype Lens 1: Completed (Milestone)	C	12/19/03
1.3.2.1.4	New Lens Operational (Milestone)	A	1/12/05
1.3.2.2	AP2 and Debuncher Acceptance		
1.3.2.2.10	Initial AP2&DB Improvements Complete (Milestone)	C	8/12/04
1.3.2.2.11	Intermediate AP2&DB Improvements Complete (Milestone)	C	8/10/05
1.3.2.2.12	Final AP2&DB Improvements Complete (Milestone)	A	12/4/06

Conclusion - The Bottom Line



Present \bar{p} yield:

$$16 \times 10^{-6} \bar{p}/\text{POT}$$

Expected \bar{p} yield:

$$36 \times 10^{-6} \bar{p}/\text{POT}$$

$$\Rightarrow 52 \times 10^{10} \bar{p}/\text{hr}$$

Delivered to the
Accumulator for
stacking

For:

8×10^{12} POT/pulse
(slip stacking)

2.0 sec cycle time